What did we learn this term?

Programming in C

Meme: Hussain Nawaz

Programming in C

DPST1091 C Language Techniques in the order they were taught

- Input/Output
- Variables
- If statements
- While statements (looping)
- Arrays
- Functions
- Pointers
- Characters and Strings
- Command Line Arguments
- Structures
- Memory Allocation
- Multi-File Projects
- Linked List
- Recursion

C as a programming language

- A compiled language
- We use **dcc** as our compiler here, but there are others
  - clang
  - gcc
  - and others . . .
- Compilers read code from the top to the bottom
- They translate it into executable machine code
- All C programs must have a **main()** function, which is their starting point
- Compilers can handle multiple file projects
- We compile C files while we **#include** H files

C and Compilation

Compiling with DCC

Compiling With GCC

Meme: Edward Ambrogio

Input/Output

Me: Mom, can I have kangaroo?
Mum: No, we have kangaroo at home
kangaroo at home:

```
printf("\n");
printf("  /\\    ___\n");
printf(" <__\\_/    \\\\\n");
printf("    \\\\_  /  _\\\\\n");
printf("      \\\\_\\\\ / \\\\\\\n");
printf("        //   \\\\\\\n");
printf("      =//     \\\\==\n");
printf("\n");
```

Meme: Khoi Nguyen

Input/Output

Scanf and Printf allow us to communicate with our user

- **scanf** reads from the standard input
- **printf** writes to standard output
- They both use pattern strings like **%d** and **%s** to format our data in a readable way

```
// ask the user for a number, then say it back to them
int number;
printf("Please enter a number: ");
scanf("%d", &number);
printf("You entered: %d ", number);
```


Alternatives for input/output

We can get and put lines and characters also

- **getchar** and **putchar** will perform input and output in single characters
- **fgets** and **fputs** will perform input and output with lines of text
- We can also use handy functions like **strtol** to convert characters to numbers so we can store them in integers

Command Line Arguments

When we run a program, we can add words after the program name

- These extra strings are given to the main function to use
- **argc** is an integer that is the total number of words (including the program name)
- **argv** is an array of strings that contain all the words

Command Line Arguments in use

```c
int main(int argc, char *argv[]) {
    printf("The %d words were ", argc);
    int i = 0;
    while (i < argc) {
        printf(" %s ", argv[i]);
        i++;
    }
}
```

When this code is run with: `$ ./args hello world`

It produces this: `The 3 words were ./args hello world`

Hello World :P

Meme: James Comninos

Variables

- **Variables**
- Store information in memory
- Come in different types:
  - **int, double, char, structs, arrays** etc
- We can change the value of variables
- We can pass the value of variables to functions
- We can pass variables to functions via pointers
- **Constants**
- **#define** allows us to set constant values that won't change in the program

Simple Variables Code

```c
// GOKU will be treated as if it's 9001 in our code
#define GOKU 9001
int main(void) {
    // Declaring a variable
    int power;
    // Initialising the variable
    power = 7;
    // Assign the variable a different value
    power = GOKU;
    // we can also Declare and Initialise together
    int power_two = 88;
}
```


if statements

Meme:Ronish Karmacharya

if statements

Questions and answers

- Conditional programming
- Evaluate an expression, running the code in the brackets
- Run the body inside the curly brackets if the expression is true (non-zero)

```c
if (x < y) {
    // This section runs if x is less than y
}
// otherwise the code skips to here if the
// expression in the () equates to 0
```


While loops

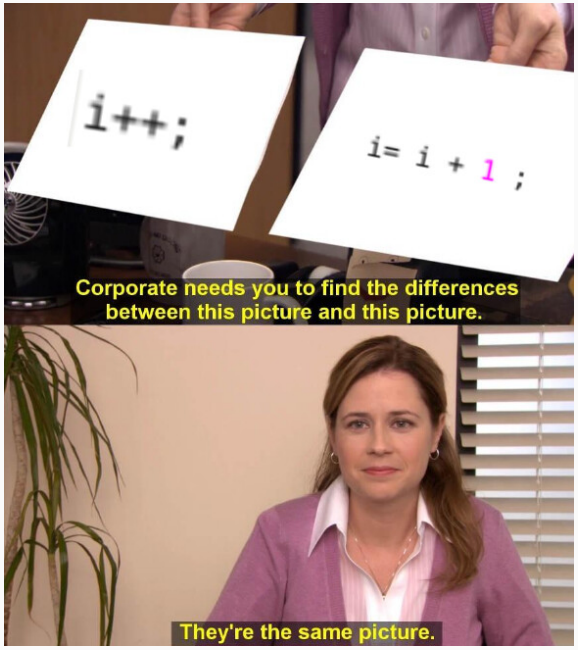
Looping Code

- While loops allow us to run the same code multiple times
- We can stop them after a set number of times
- Or we can stop them after a certain condition is met

Loops are used for . . .

- Checking all the values in a data structure (**array** or **linked list**)
- Repeating a task until something specific changes
- and any other repetition we might need

Looping



While loop code - Arrays

Very commonly used to loop through an array

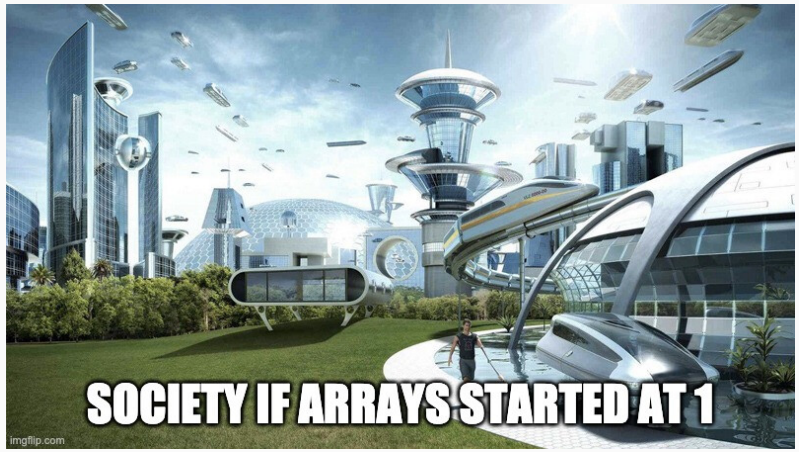
```c
int numbers[10] = { 0 };
// set array to the numbers 0-9 sequential
int i = 0;
while (i < 10) {
    // code in here will run 10 times
    numbers[i] = i;
    // increment the counter
    i++;
}
// When counter hits 10 and the loop's test fails
// the program will exit the loop
```


While loop code - Linked Lists

Looping through Linked Lists is also very common

```c
// current starts pointing at the first element of the list
struct node *current = head;
while (current != NULL) {
    // code in here will run until the current pointer
    // moves off the end of the list
    // increment the current pointer
    current = current->next;
}
// When current pointer is aiming off the end of the list
// the program will exit the loop
```


Arrays



Meme: Jayden Matthews

Arrays

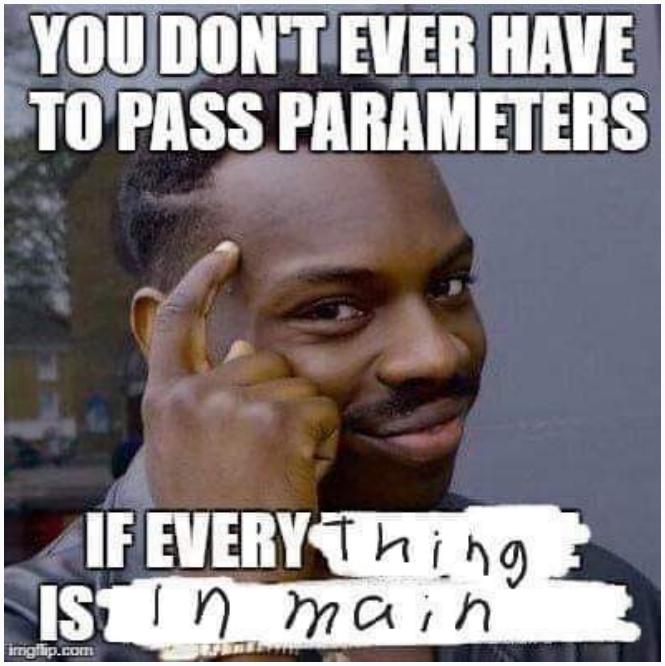
Collections of variables of the same type

- We use these if we need multiple of the same type of variable
- The array size is decided when it is created and cannot change
- Array elements arecollected together in memory
- Not accessible individually by name, but by index

Array Code

```c
int main(void) {
    // declare an array, all zeroes
    int m;
    marks[10] = {0};
    // set first element to 85
    marks[0] = 85;
    // access using an index variable
    int index = 3;
    marks[index] = 50;
    // copy one element over another
    marks[2] = marks[6];
    // cause an error by trying to access out of bounds
    marks[10] = 99;
```


Functions



Functions

Code that is written separately and is called by name

- Not written in the line by line flow
- A block of code that is given a name
- This code runs every time that name is “called” by other code
- Functions have input parameters and an output

Function Code

```c
// Function Declarations above the main or in a header file
int add(int a, int b);
int main(void) {
    int first = 4;
    int second = 6;
    int total = add(first, second);
    return 0;
}
// This function takes two integers and returns their sum
int add(int a, int b) {
    return a + b;
}
```


Pointers

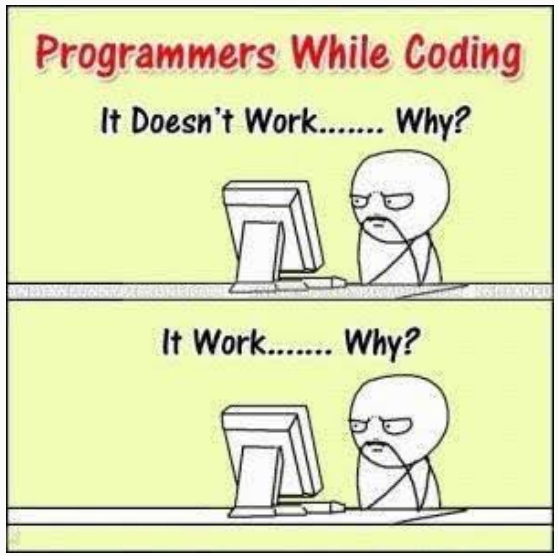
Variables that refer to other variables

- A pointer aims at memory (actually stores a memory address)
- That memory can be another variable already in the program
- It can also be allocated memory
- The pointer allows us to access another variable
- * dereferences the pointer (access the variable it's pointing at)
- & gives the address of a variable (like making a pointer to it)
- -> is used with structs to allow a pointer to access a field inside

Simple Pointers Code

```c
int main(void) {
    int i = 100;
    // the pointer ip will aim at the integer i
    int *ip = &i;
    printf("Value of variable at address %p is %d\n ", ip, *ip);
    // this second print statement will show the same address
    // but a value one higher than the previous
    increment(ip);
    printf("Value of variable at address %p is %d\n ", ip, *ip);
}
void increment(int *i) {
    *i = *i + 1;
}
```


Problem Solving

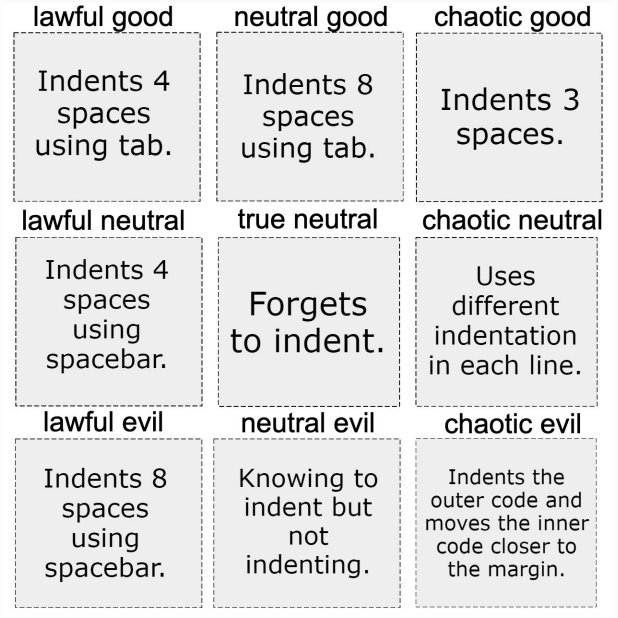


Problem Solving

Approach Problems with a plan!

- Big problems are usually collections of small problems
- Find ways to break things down into parts
- Complete the ones you can do easily
- Test things in parts before moving on to other parts

Code Style



Meme: Edison Fang

Code Style

Half the code is for machines, the other half for humans

- Remember . . . readability == efficiency
- Also super important for working in teams
- It's much easier to isolate problems in code that you fully understand
- It's much easier to get help if someone can skim read your code and understand it
- It's much easier to modify code if it's written to a good style

Code Reviews

No one has to work without help

- If we read each other's code . . .
- We learn more
- We help each other
- We see new ways of approaching things
- We are able to teach (which is a great way to cement knowledge)

Debugging

Meme: Malachi Wu

Debugging

The removal of bugs (programming errors)

- Syntax errors are code language errors
- Logical errors are the code not doing what we intend
- The first step is always: Get more information!
- Once you know exactly what your program is doing around a bug, it's easier to fix it
- Separate things into their parts to isolate where an error is
- Always try to remember what your intentions are for your code rather than getting bogged down

Professionalism

There's so much more to computing than code

- What's the most important thing for a Software Professional?
- It's not always coding!
- It's caring about what you do and the people around you!
- Even in terms of pure productivity, it's going to get more work done long term than being good at programming
- If you care about your work, you will be fulfilled by it
- If you care about your coworkers you'll teach and learn from them and you'll all grow into a great team

Course Survey - MyExperience

Please fill out the survey!

- Accessible via Moodle
- Or directly via *http://myexperience.unsw.edu.au/*
- This helps us a lot to figure out what is and isn't working in the course
- A lot of the course structure and even things like marks distribution is based on feedback from previous myExperience feedback
- We love feedback!

Characters and Strings

Meme: Jennifer Truong

Meme: Malachi Wu

Characters and Strings

Used to represent letters and words

char is an 8 bit integer that allows us to encode characters

- Uses ASCII encoding (but we don't need to know ASCII to use them)
- Strings are arrays of characters
- The array is usually declared larger than it needs to be
- The word inside is ended by a Null Terminator **'\0'**
- Using C library functions can make working with strings easier

Characters and Strings in code

```c
// read user input
char input[MAX_LENGTH];
fgets(input, MAX_LENGTH, stdin);
printf(" %s\n ", input);
// print string vertically
int i = 0;
while (input[i] != '\0') {
    printf("%c\n", input[i]);
    i++;
}
```


Structures

Custom built types made up of other types

structs are declared before use

- They can contain any other types (including other structs and arrays)
- We use a **.** operator to access fields they contain
- If we have a pointer to a struct, we use -> to access fields

Structs in code

```c
struct spaceship {
    char name[MAX_NAME_LENGTH];
    int engines;
    int wings;
};
int main(void) {
    struct spaceship xwing;
    strcpy(xwing.name, "Red 5");
    xwing.engines = 4;
    xwing.wings = 4;
    struct spaceship *my_ship = &xwing;
    // my ship takes a hit
    my_ship->engines--;
    my_ship->wings--;
}
```


Memory

Our programs are stored in the computer's memory while they run

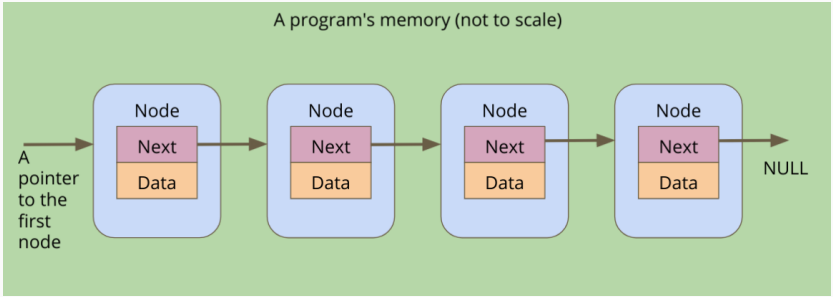
- All our code will be in memory
- All our variables also
- Variables declared inside a set of curly braces will only last until those braces close (*what goes on inside curly braces stays inside curly braces*)
- If we want some memory to last longer than the function, we allocate it
- **malloc()** and **free()** allow us to allocate and free memory
- **sizeof** provides an exact size in bytes so malloc knows how much we need

Memory code

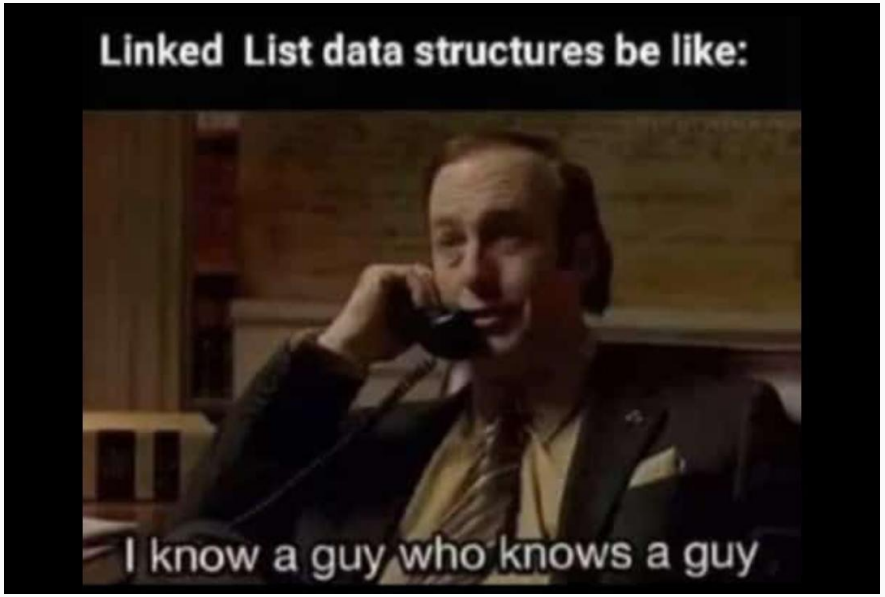
```c
struct spaceship {
    char name[MAX_NAME_LENGTH];
    int engines;
    int wings;
};
int main(void) {
    struct spaceship *my_ship = malloc(sizeof(struct spaceship));
    strcpy(my_ship->name, "Millennium Falcon");
    my_ship->engines = 1;
    my_ship->wings = 0;
    // Lost my ship in a Sabacc game, free its memory
    free(my_ship);
}
```


Linked Lists

- **Structs for nodes that contain pointers to the same struct**
- Nodes can point to each other in a chain to form a linked list
- Convenient because:
  - They're not a fixed size (can grow or shrink)
  - Elements can be inserted or removed easily anywhere in the list
- The nodes may be in separate parts of memory



Linked Lists



Meme: Caleb Watts

Linked Lists in code

```c
struct location {
    char name[MAX_NAME_LENGTH];
    struct location *next;
};
int main(void) {
    struct location *head = NULL;
    head = add_node("Tatooine", head);
    head = add_node("Yavin IV", head);
}
// Add a node to the start of a list and return the new head
struct location *add_node(char *name, struct location *list) {
    struct location *new_node = malloc(sizeof(struct location));
    strcpy(new_node->name, name);
    new_node->next = list;
    return new_node;
}
```


Complications in Pointers, Structs and Memory

What's a pointer?

- It is a number variable that stores a memory address
- Any changes made to pointers will only change where they're aiming

What does * do?

- It allows us to access the memory that the pointer aims at (like following the address to the actual location)
- This is called "dereferencing" (because the pointer is a reference to something)

What about -> ?

- Specifically access a struct at the end of a pointer
- -> must point at one of the fields in the struct that the pointer aims at
- It will dereference the pointer AND access the field
- **Pointers to structs that contain pointers to other structs!**
- We can follow chains of pointers like **track->beat->note**

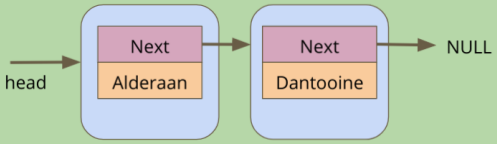
Complicated Pointer Code

```c
int main(void) {
    // create a list with two locations
    struct location *head = add_node("Dantooine", NULL);
    head = add_node("Alderaan", head);
    // create a pointer to the first location
    struct location *alderaan = head;
    // set head to a newly created location
    head = malloc(sizeof(struct location));
    // What has happened to the alderaan pointer now?
    // What has happened to the variable that the head and alderaan
    // both pointed at?
}
```

Keeping track of pointers

A program's memory (not to scale)

Create a linked list of two locations with a head pointer aimed at the first location

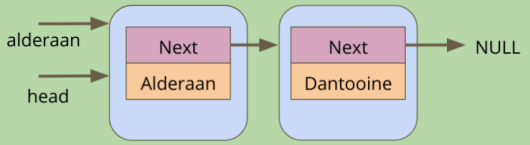


Keeping track of pointers

A program's memory (not to scale)

```
struct location *alderaan = head
```

This line creates a new pointer that's a copy of the head pointer. It is given the same value as head, which means it's aimed at the same memory address

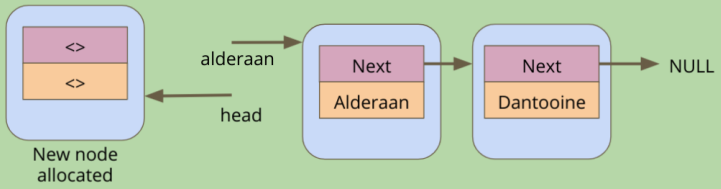


Keeping track of pointers

A program's memory (not to scale)

```
head = malloc(sizeof(struct location));
```

This line allocates new memory and assigns the address of this new allocation to the head pointer.
Changing head doesn't change the node it was pointing at!



Keeping track of pointers

Remember:

- Changing a pointer changes its value, a memory address
- Changing a pointer will change where it's aiming, nothing more!
- Once you use -> on a pointer, you're now looking at a struct field
- This means you are not changing that pointer, you have dereferenced it and accessed a field inside the struct

Abstract Data Types

Separating Declared Functionality from the Implementation

- Functionality declared in a Header File
- Implementation in a C file
- This allows us to hide the Implementation
- It protects the raw data from incorrect access
- It also simplifies the interface when we just use provided functions

Abstract Data Types Header code

```c
// Ship type hides the struct that it is
// implemented as
typedef struct ship_internals *Ship;
// functions to create and destroy Ships
Ship ship_create(char *name);
void ship_free(Ship ship);
// set off on a voyage of discovery
Ship voyage(Ship ship, int years);
```


Abstract Data Types Implementation

```c
struct ship_internals {
    char name[MAX_NAME_LENGTH];
};
Ship ship_create(char *name) {
    Ship new_ship = malloc(sizeof(struct ship_internals));
    strcpy(new_ship->name, name);
    return new_ship
}
void ship_free(Ship ship) {
    free(ship);
}
// set off on a voyage of discovery
Ship voyage(Ship ship, int years) {
    int discoveries = 0, years_past = 0;
    while (years_past < years) {
        discoveries++;
    }
    return ship;
}
```


Abstract Data Types Main

- Including the Header allows us access to the functions
- The main doesn't know how they're implemented
- We can just trust that the functions do what they say

```c
#include "ship.h"
int main(void) {
    Ship my_ship = ship_create("Enterprise");
    my_ship = voyage(my_ship, 5);
}
```

Recursion

Functions calling themselves

- A slightly inverted way of thinking about program flow
- The order of execution is determined by the Program Call Stack
- Chooses between a stopping case or a recursive case in the function

A Recursive Function in code

```c
// Print out the names stored in the list in reverse order
// This is a recursive programming implementation
void rev_print(struct player *list) {
    if (list == NULL) {
        // stopping case (there are no elements)
        return;
    } else {
        // there are element(s)
        rev_print(list->next);
        fputs(list->name, stdout);
        putchar('\n');
    }
}
```


Order of execution

- **More recursive function calls**
- Check if we're stopping, if so return
- Otherwise, call the function again with the tail (all remaining elements)
  - Check if we're stopping, if so return
  - Otherwise, call the function again with the tail (all remaining elements)
    - Check if we're stopping, if so return
    - Otherwise, call the function again with the tail (all remaining elements)
    - Then print the name of the current head of the list
  - Then print the name of the current head of the list
- Then print the name of the current head of the list

So, you're programming now . . .

Where do we go from here?

- There's so much you can do with code now
- But there's also so much to learn
- Computing has more to offer than anyone can learn in a lifetime
- There's always something new you can discover
- It's up to you to decide what you want from it and how much of your life you want to commit to it
- Remember to care for yourselves and your work
- Enjoy yourselves, keep working on what you love and I hope to bask in your future glory

- Good luck, have fun :)